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# TECHNICAL NOTE

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## VANGUARD SATELLITE SEPARATION MECHANISMS

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## SUMMARY

Early in the Vanguard program it became apparent that a thoroughly reliable means of separating the satellite packages from the third-stage rocket would be required. A completely self-contained standard mechanism was developed with redundant firing circuits for use on both test vehicles and satellite-launching vehicles.

A change in the experimental objectives of the test-vehicle payload units necessitated modification of some of the standard separation mechanisms. A strap, pull-pin, girth-ring separation device was developed which employed the basic actuation of the standard mechanisms.

Evidence of residual burning of the third stage made it necessary to delay separation longer than the time designed into the long-delay separation device. The standard separation mechanism was modified and integrated with the satellite command receiver system so that a ground command after third-stage burnout would cause separation.

Flight performance of the various separation mechanisms proved their reliability; they performed without failure in all Vanguard launchings.



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## INTRODUCTION

Early in the Vanguard program it became apparent that a thoroughly reliable means was needed to separate the satellite packages from the third-stage rockets after burnout. The satellite configurations were symmetrical about any axis and therefore presented the same projected area in any direction after separation from the rocket. This characteristic was desirable for two reasons: drag computations, and thermal considerations in orbit. With a symmetrical satellite, orientation with respect to the orbital path, the earth, and the sun is not critical from a drag or thermal standpoint.

Specifications for the desired mechanism were drawn up, and requests for proposals were sent to numerous contractors and to certain government agencies. Careful evaluation of each of the submitted proposals resulted in the selection of one designed by Raymond Engineering Laboratories of Middletown, Connecticut. The proposed mechanism was a completely self-contained unit actuated by the acceleration characteristics of the third-stage rocket. Redundant firing circuits were employed for reliability and in order to utilize, wherever possible, components with proven high reliability. The proposed unit was to weigh no more than 1 pound and was to impart a differential velocity of 3 feet per second to a 21.5-pound payload. The same basic mechanism was to be used for both the test-vehicle payload spheres and full-sized Vanguard satellites.

## STANDARD SEPARATION MECHANISM

### General

The original minimal satellite (Figure 1), intended primarily for use as a test vehicle payload, was to utilize the same mechanism for separation as the full-scale 20-inch diameter Vanguard satellite (Figure 2), except that a less powerful ejection spring would be employed. The separation mechanisms were produced on this basis. After their delivery, however, the design of the minimal satellite was radically changed (Figure 3), making it

necessary to modify some of the mechanisms for use with the new sphere design. The unbalanced weight of the original, or standard separation mechanism is 0.88 pound.

## Operation

To arm and "fire" the separation mechanism, the acceleration characteristics of the third-stage rocket are utilized (Figure 4). The operation of the standard mechanism (Figure 5) may be described as follows: If an acceleration of approximately 12 g or more is applied for over 2 seconds, the timer will be allowed to run for an additional 10 seconds to a stop on the g-weight arm. (If the 12 g acceleration is applied for less than 2 seconds, the unit will reset itself.) When the acceleration is reduced below approximately 12 g at third-stage burnout, the timer will start and will run approximately 30 seconds (the standard short-delay timer) or up to 300 seconds (the standard long-delay timer). At the end of this period the timer arm closes the two firing circuits connecting the batteries through the caterpillar motors (explosive motors). The motors expand, pull in the hold-down pin, and rotate the spring release. When released, the spring imparts a differential velocity of approximately 3 feet per second between the burned-out third stage and the satellite.

The operation sequence just described was not arrived at arbitrarily. The 2-second arming time with 12 g or more acceleration insures that premature firing will not be caused by either shock or vibration. The additional 10-second arming time before the stop on the g-weight arm is reached insures that slight variations in third-stage rocket acceleration\* will not cause premature separation by releasing the timer arm from the g-weight arm and allowing the firing sequence to be completed.

Initially, all of the separation mechanisms contained standard short-delay (approximately 30-second) timers. Between the launch operations for Satellite Launching Vehicle (SLV†) No. 2 and No. 3, operations, tests of the Grand Central Rocket Company's third-stage rocket motor gave indications that residual burning in the motor lasted much longer than had previously been believed. Residual burning causes a small amount of thrust from the third-stage motor *after* cessation of the main thrust at burnout. In order to eliminate the possibility of a collision between the third-stage rocket and the satellite, it was necessary to leave the satellite attached until after residual burning had ceased. The separation mechanisms for the remaining SLV flights were therefore modified to allow up to 5 minutes delay before separation; hence, the standard long-delay (up to 300-second) timer.

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\*The normal acceleration (burning) time, of course, considerably exceeds the 12 seconds required to arm the separation mechanism.

†As distinguished from the Test Vehicle (TV) series which preceded the full-scale satellite launching operations.



Throughout the Vanguard program, the satellite separation mechanisms operated in flight without failure (Table 1). A thorough inspection and checkout procedure was established and used during the preflight field operations. Special battery tests, squib tests, timer tests, etc. were devised to insure good reliability. The manufacturer, Raymond Engineering Laboratories, gives a reliability figure of 1 in 3000 for the mechanism.

## Testing

The testing of the standard separation mechanism may be divided into two general categories: prototype testing, and flight unit testing. The established Vanguard test specifications (Reference 1) were followed. In addition to the required Vanguard tests, numerous other component and assembly tests were performed. For example, a combined centrifuge and vibration test applying accelerations of 8 to 30 g combined with 8-g sinusoidal vibration from 20 to 100 cycles per second (the limit of the available equipment), was given a prototype unit. Special tests were devised to insure reliable performance of the caterpillar motors, including numerous vacuum firings and sample batch firings. Selection of the most reliable caterpillar motors was accomplished by means of resistance checks; it was determined that if the internal resistance was over 7 ohms, the reliability was lowered and the unit was probably not sealed properly. A battery test was also devised. It was found, in measuring the open circuit voltage of the battery, applying a 50-milliampere load, and recording voltages at 30 seconds and 1 minute (then removing the load), that the battery voltage should increase slightly from the 30-second to the 1-minute check point; otherwise the reliability of the battery was questionable.

All of the separation mechanisms were checked for proper operation on a programmed centrifuge at the Diamond Ordnance Fuze Laboratories in Washington, D. C. The test may be described briefly as follows: A typical third-stage acceleration-vs-time curve was cut on dark film. The film was placed on a cathode-ray tube, and a pinpoint of light is focused on the screen (from within the tube). This light beam followed the acceleration-vs-time curve, and the associated electronics caused the centrifuge to follow the desired acceleration program. The sweep time and acceleration limits were preset in the equipment, and the desired program was followed. In order to monitor the operation of the mechanism during this test, a small 360-degree potentiometer was connected to the timer, and timer functions were transmitted through slip rings and recorded on a Sandborn recorder. Simultaneously an accelerometer, located at the mechanism, gives the acceleration level of the mechanism, and this information is recorded on the same Sanborn tape. The resultant recording indicated the arming g level, the actuation g level, and time functions of the mechanism.

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Table 1  
Summary tabulation of Vanguard satellite separation mechanisms

Vehicle	Satellite type	Separation device type	Separation device Unit No.	Remarks
TV-3	Test-vehicle sphere	Strap, pull-pin	22	*
TV-3BU	Test-vehicle sphere (life science)	Strap, pull-pin	8	*
TV-4	Test-vehicle sphere (Vanguard I - 1958 Beta 2)	Strap, pull-pin	21	Separation occurred at $T + 664$ seconds
TV-5	X-Ray, 20" sphere	Standard (short-delay)	11	*
SLV-1	Lyman Alpha, 20" sphere	Standard (short-delay)	3	Separation occurred at $T + 627$ seconds
SLV-2	X-Ray, 20" sphere	Standard (short-delay)	12	*
SLV-3	Cloud Cover, 20" sphere	Standard (long-delay)	15	Separation occurred at $T + 737$ seconds
SLV-4	Cloud Cover, 20" sphere (Vanguard II - 1959 Alpha)	Standard (long-delay)	6	Separation occurred at $T + 772.5$ seconds
SLV-5	Magnetometer, 13" sphere	Standard (long-delay)	20	*
SLV-6	Radiation Balance of the earth, 20" sphere	Command Separation System	23	*
SLV-7	X-Ray - Magnetometer, 20" sphere	No separation required	—	

\*Vehicle did not perform properly through third-stage burning; hence, separation device did not receive necessary acceleration to cause arming and firing.

All separation mechanisms were dynamically balanced prior to flight use. The degree of balance required was approximately 0.1 inch-ounce. The balancing equipment was the same as that used for balancing satellites.

## MODIFIED SEPARATION MECHANISM

### General

During the vehicle test program, a change in the experimental objectives of the launching vehicle necessitated a redesign of the test-vehicle payload sphere or minimal satellite. One of the needed revisions required the separated test-vehicle sphere to be completely symmetrical about any axis. It was necessary, therefore, to devise a method of holddown and separation on this basis.

Initially, three methods were considered for adapting the basic mechanism for use in separating the new test-vehicle payload sphere: (1) a strap, explosive-bolt method (Figure 6); (2) a strap, pull-pin method, and (3) a strap, pull-pin, girth-ring method. The strap, pull-pin, girth-ring method was adopted as being the most reliable (Figure 7 and 8).

The developmental work on this modified mechanism was done by Vanguard personnel and a prototype, drawings, and specifications were then submitted to the Raymond Engineering Laboratories to expedite the modification of six standard units. The modifications were performed as follows: (1) removing unnecessary components from the standard mechanism (release-spring assembly and mechanism), (2) modifying the internal configuration at the base of mechanism to insure against buckling by the explosive motors, and (3) manufacture of the new release device consisting of strap, girth rings, and separation sleeve.

### Operation

The operation of the modified mechanism is identical to that of the standard mechanism with one exception: The pulling in of the hold-down pins by the caterpillar motors releases the girth rings instead of the ejection spring (Figure 9). When the strap (held by the girth rings) is assembled to the test-vehicle sphere, it is torqued to provide a tensile load of 100 pounds which is required to hold the test-vehicle sphere in place under flight environmental conditions. Upon release the strap springs off the crown of the sphere, three small leaf springs, located directly under the sphere on the separation sleeve, separate the sphere from the third stage with a differential velocity of approximately 1 foot per second.

## Testing

The test program for the modified separation mechanisms was quite similar to that for the standard mechanisms. To study the actual separation a Fastax camera was used to photograph the separation sequence (Figure 10). The sphere was "suspended" from a thin spring-steel ribbon that passed over low-friction rollers and attached to a counter-weight which exactly balanced the weight of the sphere, which was held by the separation mechanism. The caterpillar motors were fired by an external battery, and the camera recorded the separation sequence.

The separation velocity was obtained by experimentally determining the kinetic energy in the three small leaf springs as they were installed on the separation sleeve. Several sleeves were used, and an average separation velocity was determined; the actual velocity was not critical.

## COMMAND SEPARATION

### General

Just prior to the SLV-6 satellite launching attempt, evidence was presented by the optical tracking team that residual burning of the third stage lasted considerably longer than 5 minutes. The team had located the expended third-stage bottles placed in orbit along with the Vanguard I and Vanguard II satellites, and had determined that they were in larger orbits than their respective satellites. The increase in third-stage rocket velocity after satellite separation had to be in the order of 200 feet per second to provide such orbits.

Two courses of action were taken for the next satellite launching attempt: (1) modification of the separation timers to extend the delay time from 5 to 15 minutes, and (2) modification of the separation units so that separation would occur upon ground-based command. The two systems were pursued, one as a back-up for the other, because of the limited time available before the next satellite attempt. There was no positive evidence that 15 minutes would be long enough to assure that residual burning of the third stage had ceased, but the risk was reduced by a factor of at least 3. The systems were both completed and tested in time, and the command system finally was selected for the launching.

## Operation

The command system required utilizing the existing command receiver in the satellite as well as the satellite battery power. The operation was as follows: The separation mechanism went through the standard operational sequence described earlier but, when the two firing circuits were closed, the mechanism was merely armed to await the command from the ground, which would then cause satellite separation. The arming feature made possible a complete satellite checkout on the stand just prior to the launching without causing premature separation.

## Testing

The test program for the separation mechanisms with the 15-minute timers was similar to that used for standard separation mechanisms. The command separation system also was tested similarly as far as environmental conditions were concerned, i.e., acceleration, vibration, etc.; but additional tests were added. One of the additional tests consisted of an actual command separation after the satellite - and-mechanism combination had completed the flight-level vibration tests.

## CONCLUDING REMARKS

Three separation mechanisms employing the same basic actuation principles were developed for use in Project Vanguard (Table 2). All of these mechanisms proved reliable in flight. The actuation mechanism could be miniaturized to effect a further weight saving. The size and shape of the standard separation mechanism were, to a large extent, dictated by the satellite design and by certain vehicle parameters.

Certainly the fundamental principles developed can be of use in future satellite and space programs; numerous types of highly reliable special devices for separating one unit from another in space will certainly be required. Explosive bolts, springs, mechanical releases, gas jets, acceleration actuators, pressure actuators, temperature actuators, and small solid-propellant rocket motors, are some of the various methods that have been and continue to be used. The basic philosophy of making the separation device a self-contained unit with independent operation and checkout promotes maximum reliability, since a close control can be maintained on the mechanisms.

Table 2

## Summary History of Vanguard Satellite Separation Mechanisms

Serial number	Type of mechanism	Location and/or disposition	
1	Original prototype	Dismantled after test period	
2	Original prototype tested and converted to long-timer prototype	On hand*	
3	20" unit 30-second timer	SLV-1	5-27-58
4	20" unit 30-second timer	On hand*	
5	Minimal prototype mechanism	On hand*	
6	20" unit long timer	SLV-4	2-17-59
7	Converted to spin-retarding mechanism (prototype)	On hand*	
8	Minimal 30-second timer	TV-3BU	2- 5-58
9	20" unit 30-second timer	On hand*	
10	Converted to spin-retarding mechanism	SLV-4	2-17-59
11	20" unit 30-second timer	TV-5	4-29-58
12	20" unit 30-second timer	SLV-2	6-26-58
14	Converted to spin-retarding mechanism	SLV-3	9-26-58
15	20" unit long timer	SLV-3	9-26-58
16	20" unit long timer	On hand*	
17	Converted to spin-retarding mechanism	SLV-5	On hand*
18	20" unit 30-second timer	On hand*	
19	20" unit 30-second timer	On hand*	
20	20" unit long timer	SLV-5	On hand*
21	Minimal 30-second timer	TV-4	3-17-58
22	Minimal 30-second timer (Above unit was recovered and rebuilt)	TV-3	12- 6-57
23	20" unit Command Separation System	SLV-6	On hand*

\*At termination of Vanguard program.

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The Raymond Engineering Laboratory, Middletown, Connecticut, which produced and modified the separation mechanisms.

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The Naval Research Laboratory, Washington, D. C. which provided vibration test facilities, shop facilities, and many other necessary services.

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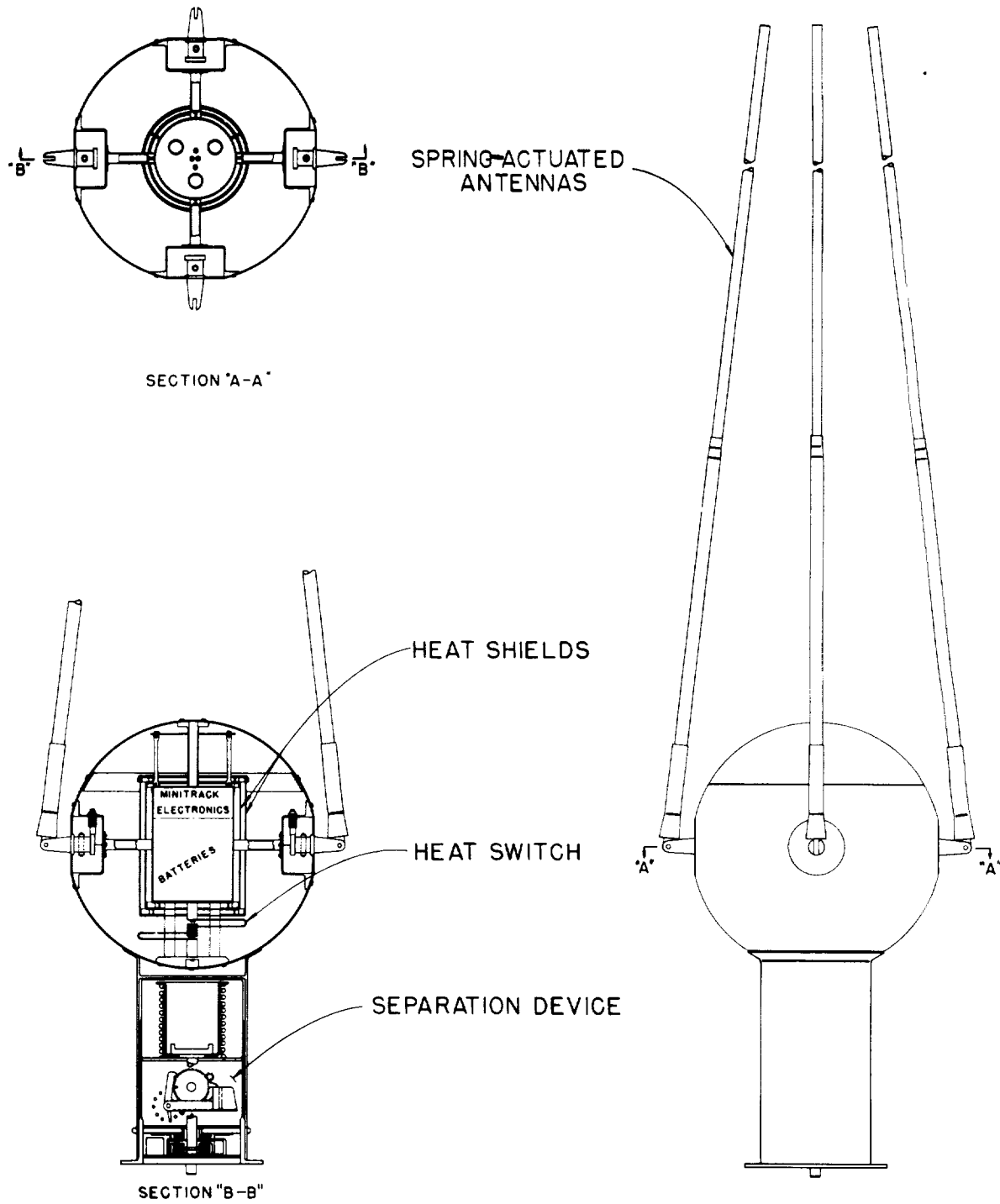


Figure 1 - Minimal satellite



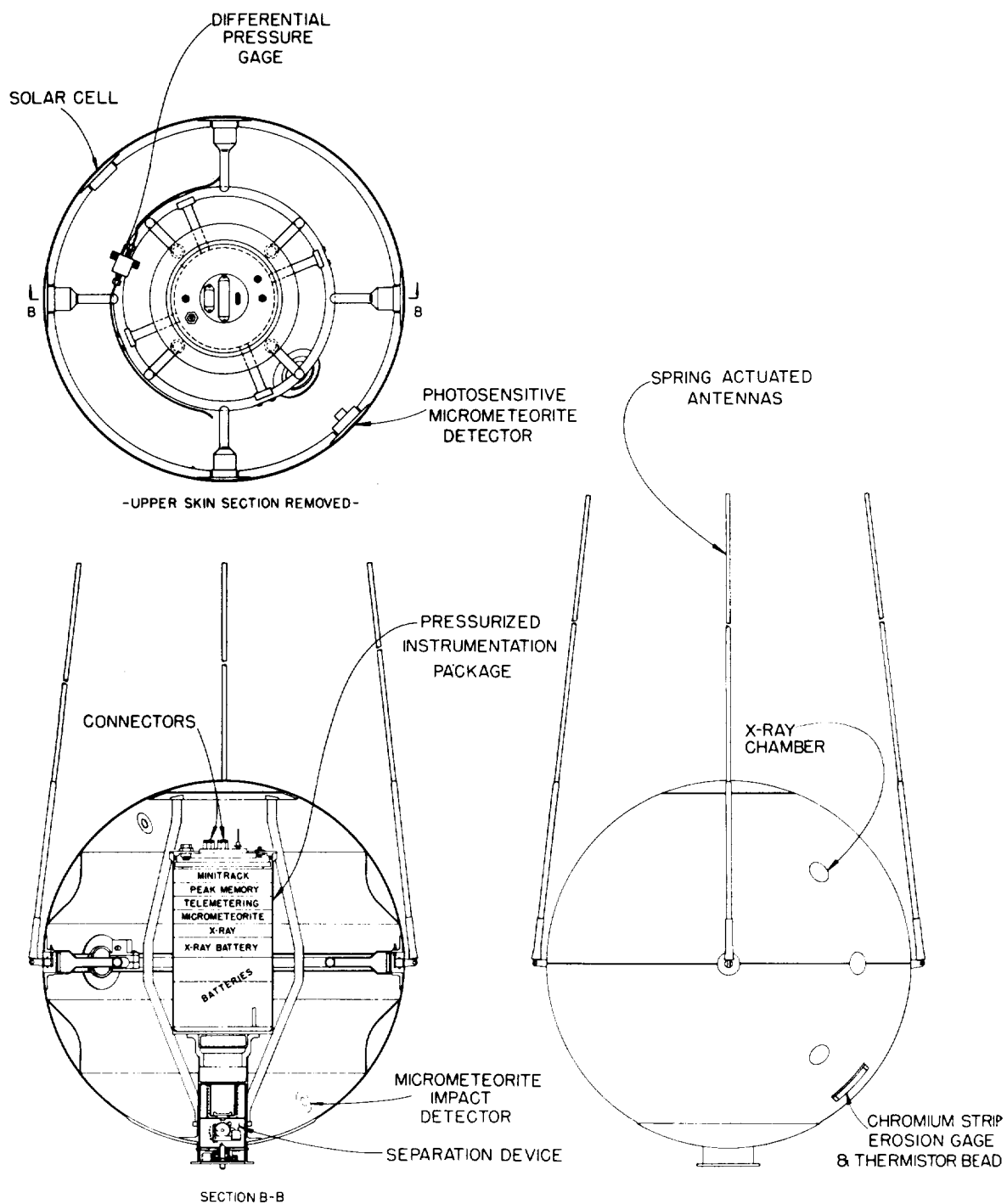


Figure 2 - Typical separation device installation in SLV series satellites

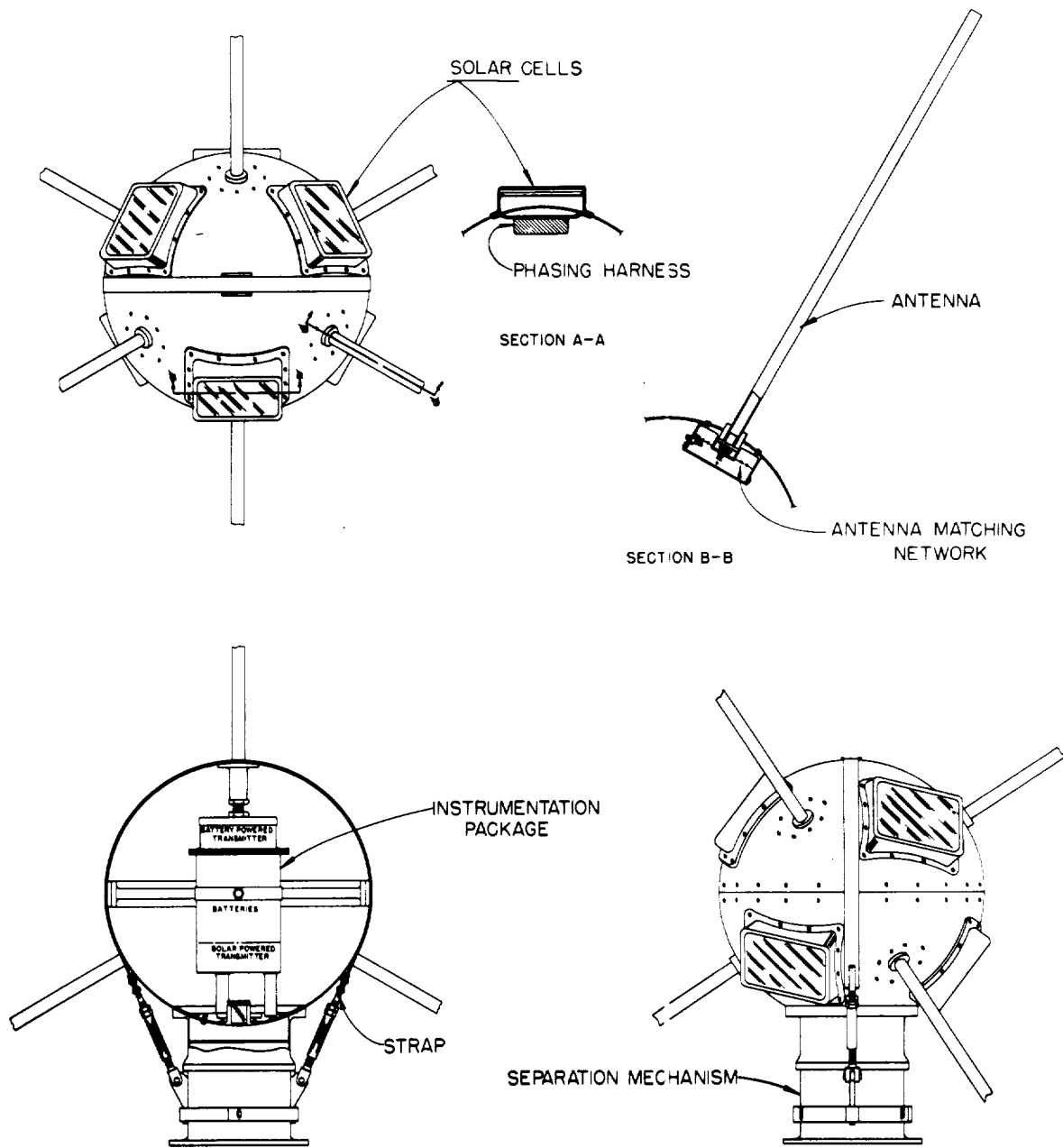


Figure 3 - Test vehicle payload sphere

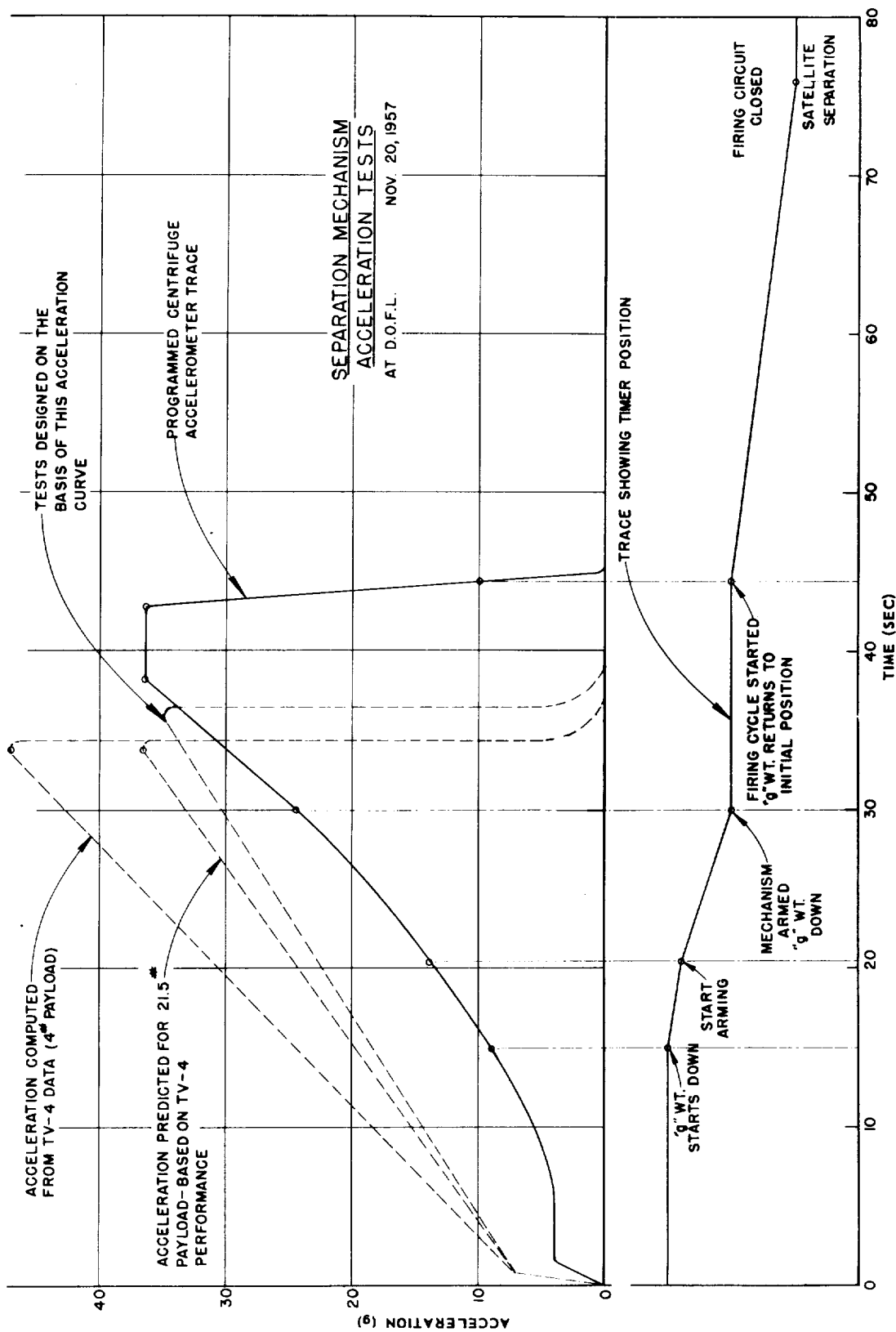
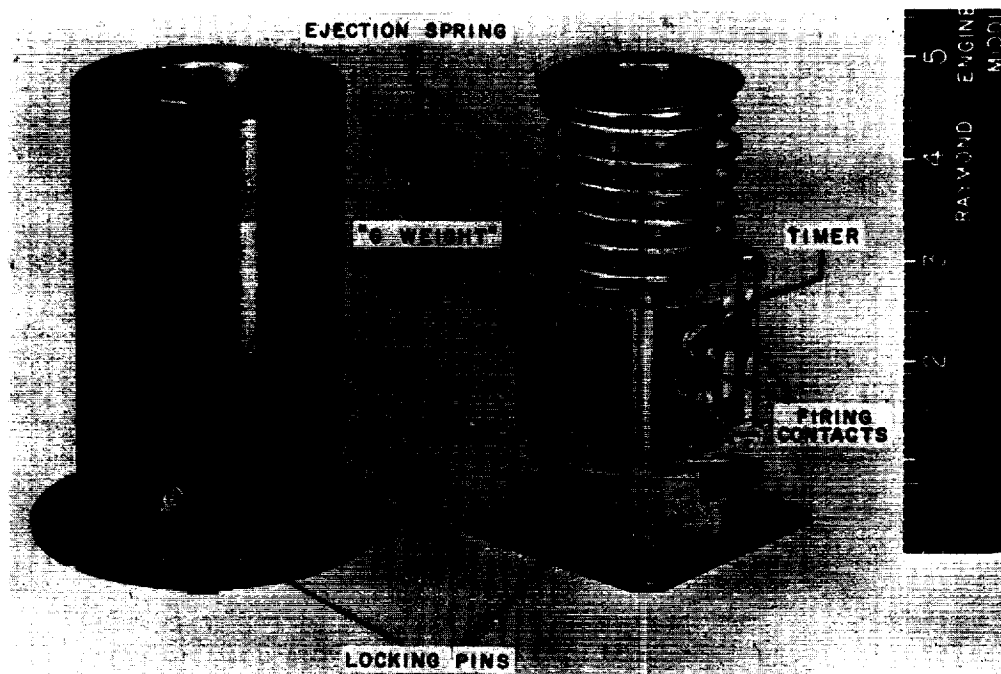
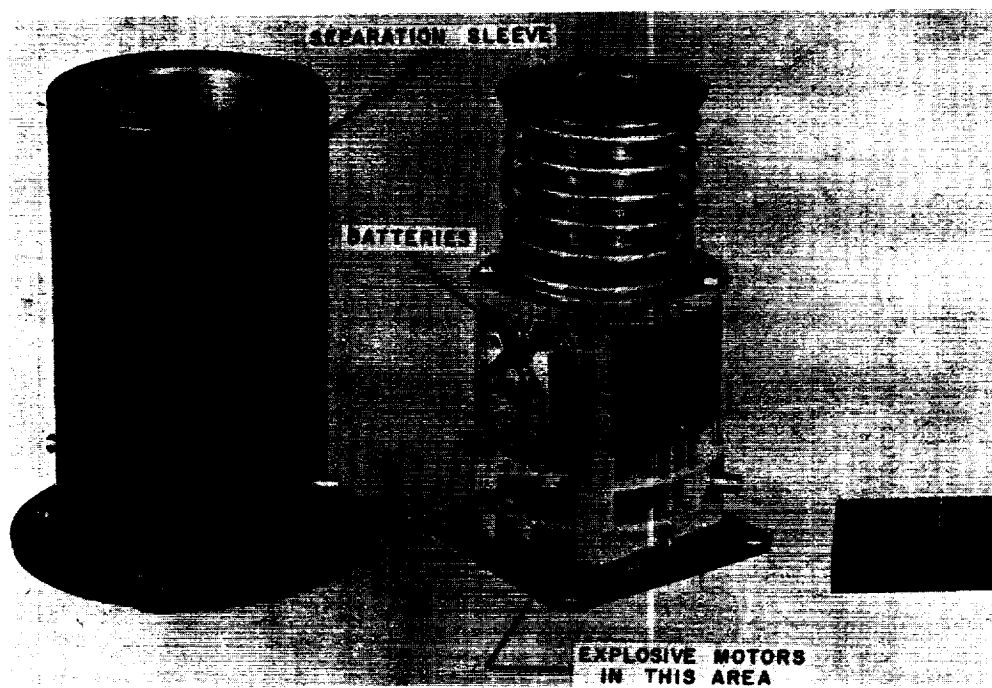


Figure 4 - Separation - mechanism acceleration tests



FRONT VIEW



REAR VIEW

Figure 5 - Satellite separation mechanism

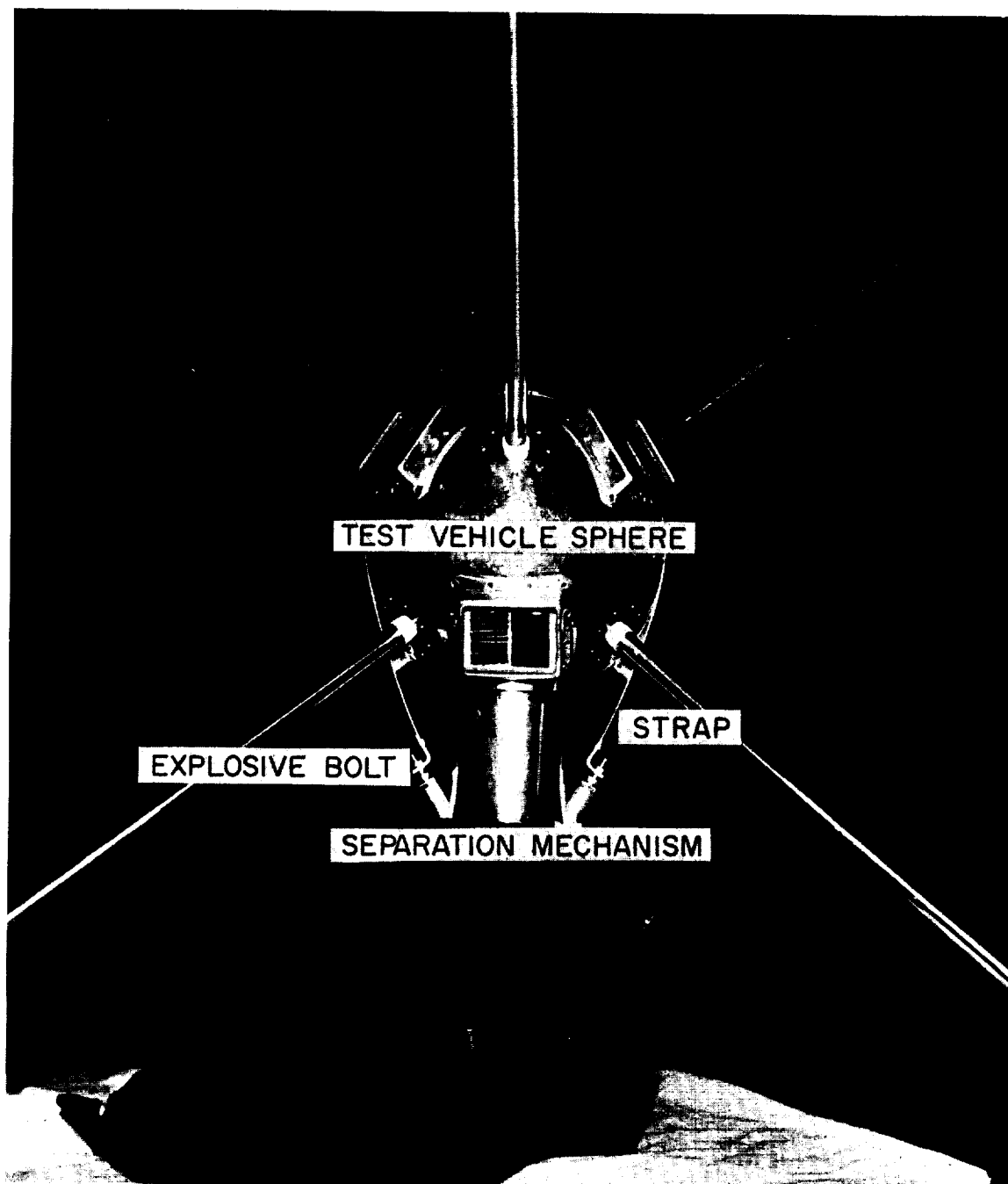


Figure 6 - Strap, explosive-bolt method

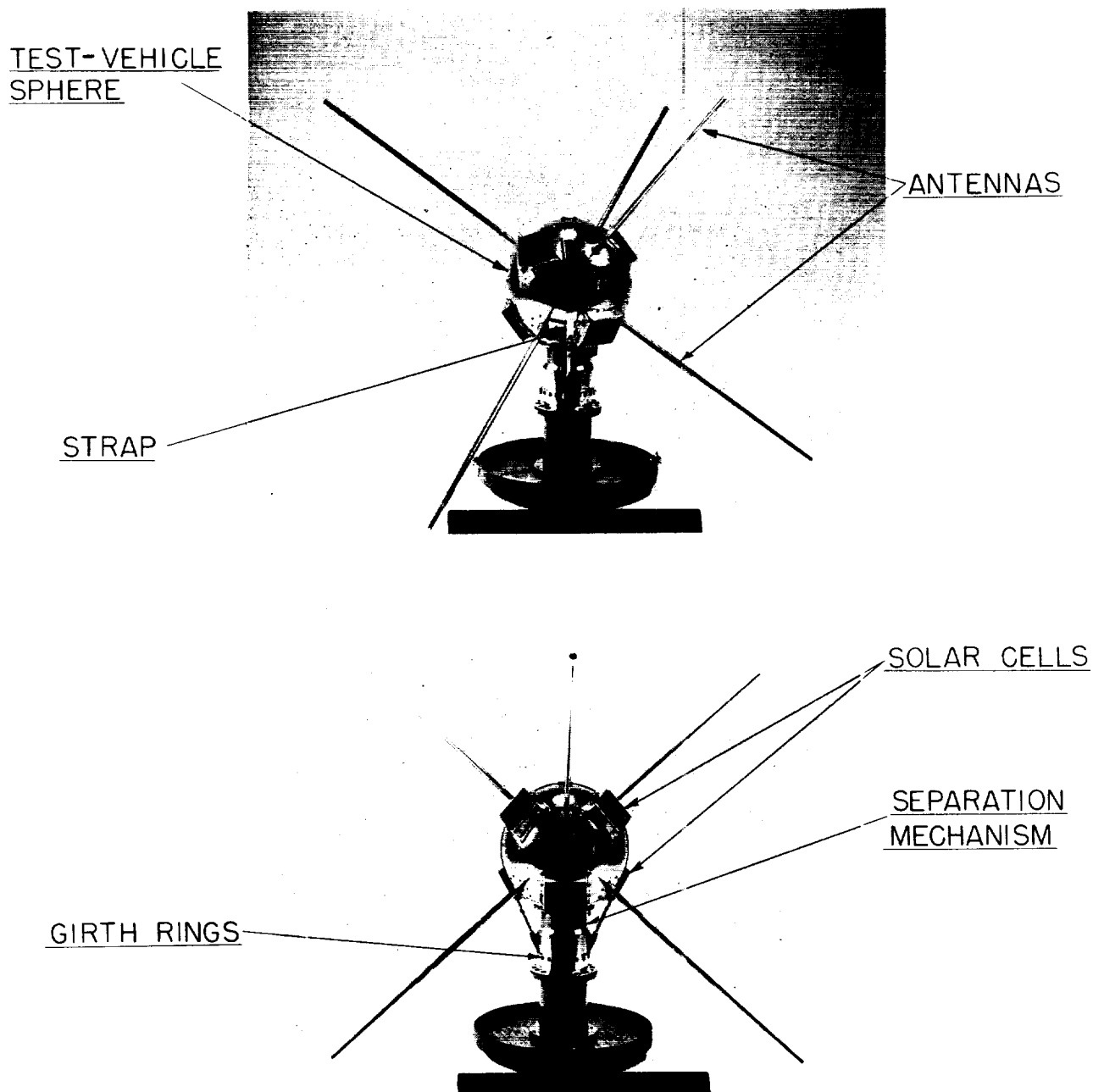


Figure 7 - Test-vehicle sphere mounted on separation mechanism

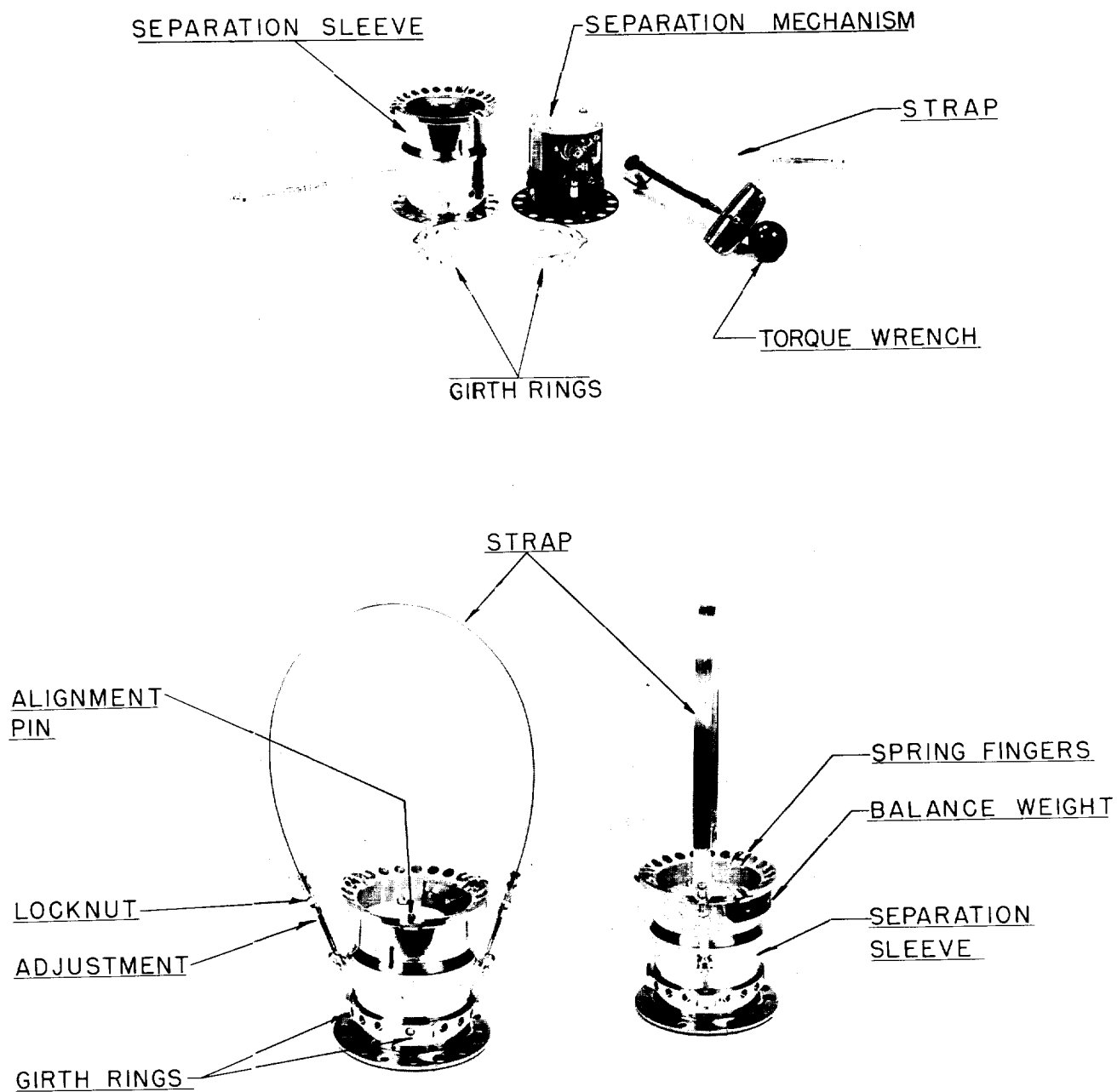
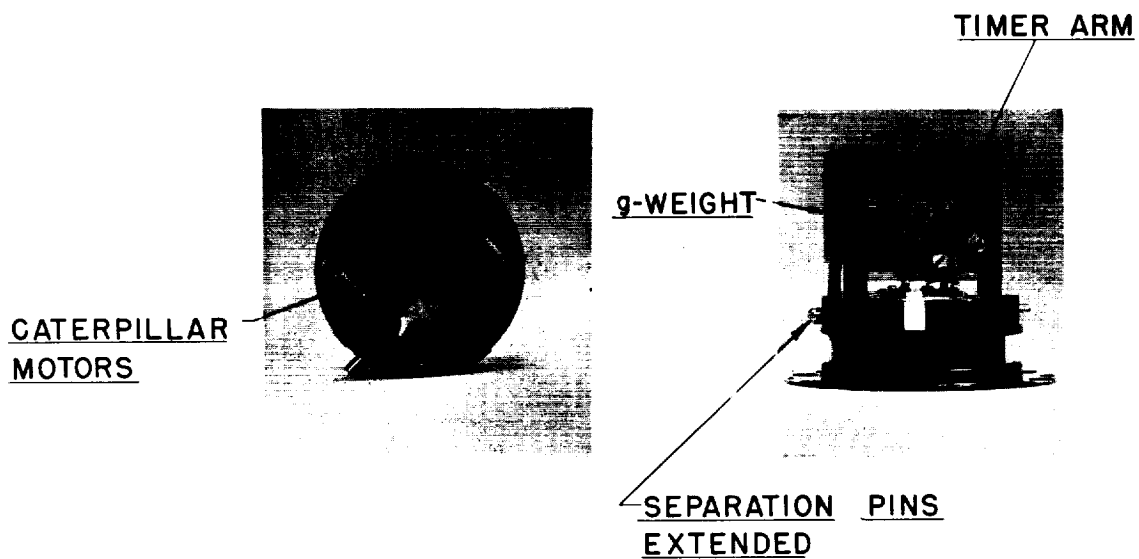


Figure 8 - Test-vehicle-sphere separation device



(a) Unfired position

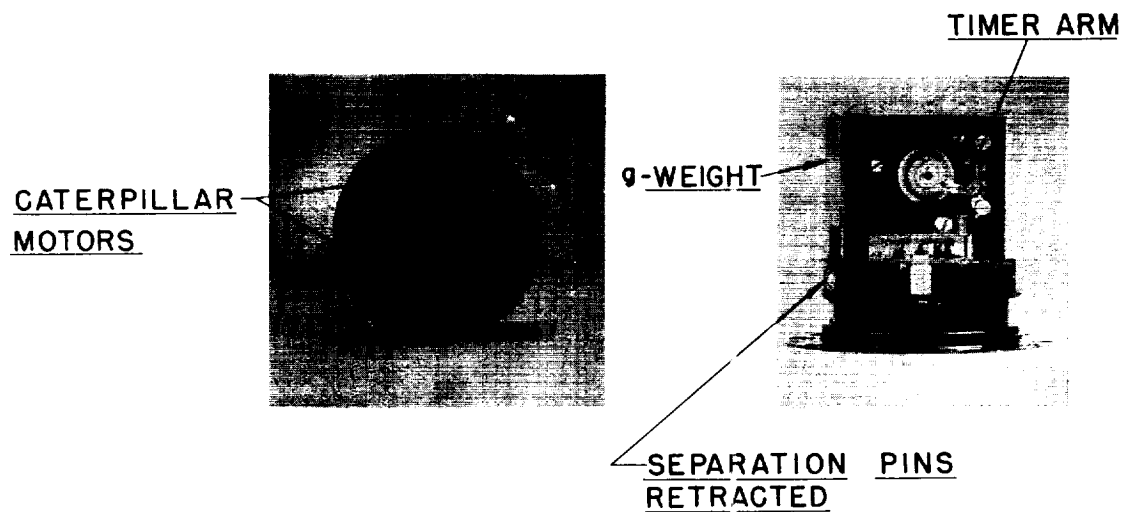
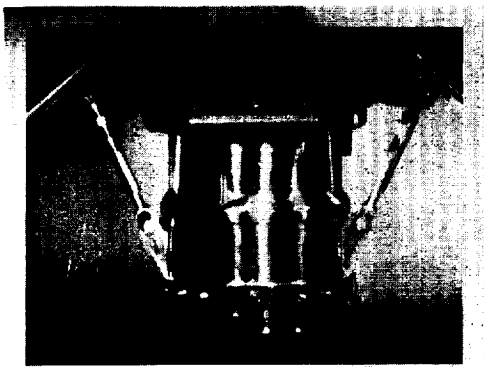


Figure 9 - Separation mechanism in unfired and fired positions

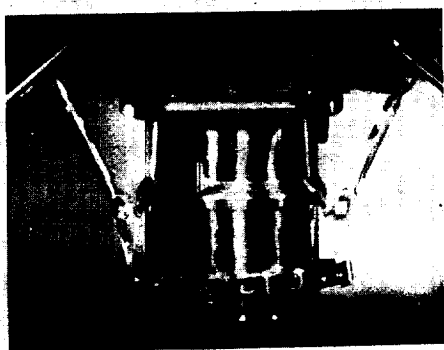




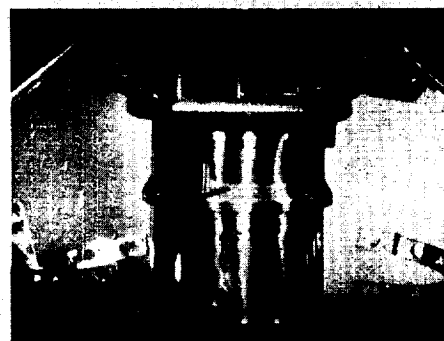
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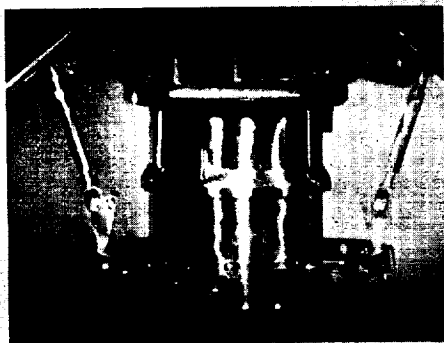
+.0104 SECONDS



+.0035 SECONDS



+.0139 SECONDS



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+.0174 SECONDS

Figure 10 - Test-vehicle-sphere separation

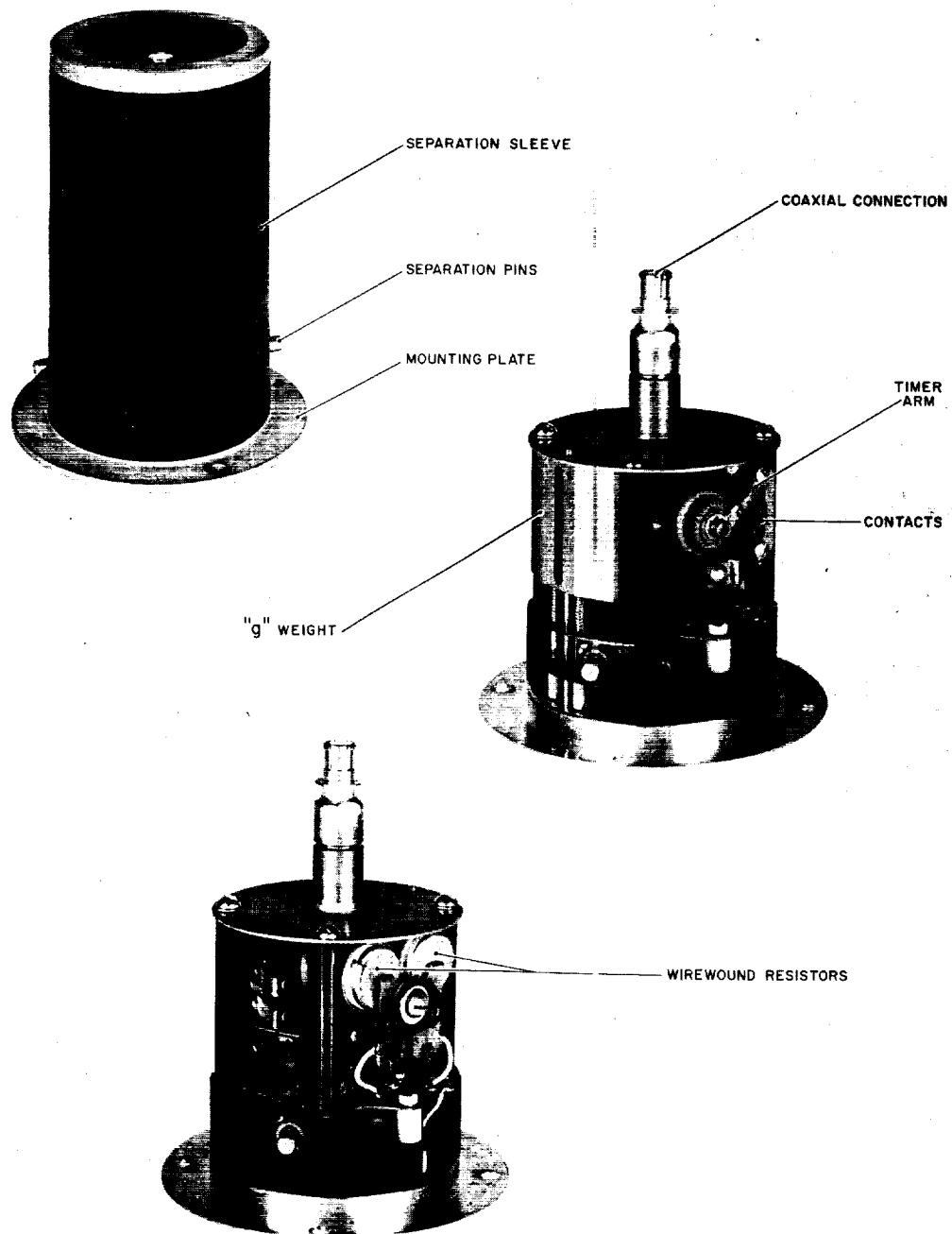


Figure 11 - Command separation mechanism for SLV-6